



Use of Non-Vital Pulp Therapies in Primary Teeth

James A. Coll, DMD, MS¹ • Vineet Dhar, BDS, MDS, PhD² • Kaaren Vargas, DDS, PhD³ • Chia-Yu Chen, DDS⁴ • Yasmi O. Crystal, DMD, MSc⁵ • Shahad AlShamali, B.Med.Sc, BDM, MS⁶ • Abdullah A. Marghalani, BDS, MSD, DrPH⁷

Abstract: Purpose: To present an evidence-based guideline for non-vital pulp therapies due to deep caries or trauma in primary teeth. **Methods:** The authors, working with the American Academy of Pediatric Dentistry, conducted a systematic review/meta-analysis for studies on non-vital primary teeth resulting from trauma or caries and used the GRADE approach to assess level of certainty of evidence for clinical recommendations. **Results:** GRADE was assessed from high to very low. Comparing teeth with/without root resorption, pulpectomy success was better ($P < 0.001$) in those without preoperative root resorption. Zinc oxide plus iodoform plus calcium hydroxide ([ZO/iodoform/CH]; Endoflas™) and zinc oxide and eugenol (ZOE) pulpectomy success did not differ from iodoform (iodoform plus calcium hydroxide; Vitapex™, Metapex™) ($P = 0.55$) after 18-months; however, ZO/iodoform/CH and ZOE success rates remained near 90 percent while iodoform was 71 percent or less. Network analysis ratings showed ZO/iodoform/CH and ZOE better than iodoform. Lesion sterilization tissue repair (LSTR) was better ($P < 0.001$) than pulpectomy in teeth with preoperative root resorption, but pulpectomy results were better ($P = 0.09$) if roots were intact. Rotary instrumentation of root canals was significantly faster ($P < 0.001$) than manual, but the quality of fill did not differ ($P = 0.09$) and both had comparable success. Network analysis ranked ZO/iodoform/CH the best, ZOE second, and iodoform lowest at 18 months. Success rates were not impacted by method of obturation or root length determination, type of tooth, number of visits, irrigants, smear layer removal, or timing/type of final restoration. **Conclusions:** Pulpectomy 18-month success rates supported ZO/iodoform/CH and ZOE pulpectomy over iodoform. LSTR had limited indication for teeth with resorbed roots and requires close monitoring. (Pediatr Dent 2020;42(5):337-49) Received April 16, 2020 | Last Revision June 13, 2020 | Accepted June 15, 2020

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Plain language summary

Purpose. Untreated decay or trauma can cause the nerve of the tooth to become irreversibly inflamed, abscessed, or dead. The diagnosis is based on both clinical and radiographic signs and symptoms, such as a toothache waking the child in the middle of the night, unprovoked toothache, gum or facial swelling, or X-rays showing the tooth has bone loss or root resorption. Treatment options for this condition include extraction, root canal therapy (pulpectomy), or lesion sterilization tissue repair (LSTR), which involves the placement of antibiotics inside the tooth. This manuscript evaluates available treatment options to save baby (primary) teeth with dying (irreversibly inflamed), dead (necrotic), or abscessed nerve (pulp) resulting from decay or trauma and various factors that impact the treatment's success (e.g., eliminate pain and swelling or pathology on follow-up X-rays).

Methods. The authors, working with the American Academy of Pediatric Dentistry, systematically reviewed all the dental literature up to January 2020 on the subject of non-vital (irreversibly inflamed, necrotic) primary tooth pulp treatments. This systematic review used 114 articles published between 1972 and 2020 that included randomized and nonrandomized controlled trials as well as studies done in laboratories. The authors defined treatment success as the child having no pain or infection and radiographs showing no signs of pathology.

Results. Pulpectomy has a high success rate and can be used for the treatment of dead, dying or abscessed primary teeth with no evident root resorption. In teeth with no root resorption, pulpectomy should be chosen over LSTR. Follow-up X-rays should be taken at least every 12 months to monitor the treatment. LSTR should be chosen over pulpectomy in teeth with root resorption or to retain teeth for up to 12 months that otherwise would be extracted. LSTR treatment should be monitored closely in the first year, and after the first year, with periodic clinical examinations and X-rays at least every 12 months. Pulpectomy and LSTR compared to extraction maintain the tooth in the arch and eliminate any pain and infection, and the procedure should not cause severe pain after 1-2 days. Root canal filling materials such as zinc oxide and eugenol (ZOE), iodoform, or zinc oxide/iodoform/calcium hydroxide (ZO/iodoform/CH) are used to fill the root canal space after the infected pulp is removed. For teeth expected to be in the mouth for 18 months or longer, zinc oxide/iodoform/CH and ZOE fillers performed better than iodoform fillers. The use of motor-driven rotary root canal files to instrument the root canals is faster than hand instrumentation but does not affect treatment success or quality of filling the root canals. Pulpectomy success also was not affected by different methods of filling the root canals (Lentulo spiral, hand pluggers, or syringe), type of tooth

¹Dr. Coll is a clinical professor and ²Dr. Dhar is a clinical professor and chair, Department of Orthodontics and Pediatric Dentistry, University of Maryland School of Dentistry, Baltimore, Md., USA. ³Dr. Vargas is a pediatric dentist in private practice, North Liberty, Iowa, USA. ⁴Dr. Marghalani is an assistant professor, Department of Preventive Dentistry, Umm Al-Qura University, Makkah, Saudi Arabia. ⁵Dr. Chen is a pediatric dentist in private practice, Bel Air, Md., USA. ⁶Dr. AlShamali is a pediatric dentist, AlAmiri Specialized Dental Center, Ministry of Health, Kuwait City, Kuwait. ⁷Dr. Crystal is a clinical professor, Department of Pediatric Dentistry, New York University College of Dentistry, New York, N.Y., USA.

Correspond with Dr. Coll at jimcollmdm@gmail.com

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GLOSSARY OF TERMS AND ABBREVIATIONS

95% CI refers to 95 percent confidence interval.

AAPD: American Academy of Pediatric Dentistry.

Alternate 3Mix used in LSTR is an antibiotic modification of traditional 3Mix in which tetracycline/minocycline is replaced by another antibiotic such as clindamycin.

CH is a calcium hydroxide pulpotomy.

DPC (Direct pulp treatment) is done for pinpoint pulp exposures after caries removal and is sealed with a biocompatible material.

FC is a formocresol pulpotomy.

FS is a ferric sulfate pulpotomy.

GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) provides a framework for specifying health care questions, choosing outcomes of interest and rating their importance, evaluating the available evidence, and bringing together the evidence with considerations of values and preferences of patients and society to arrive at recommendations.

I² statistic is a measurement of inconsistency of the data included in the meta-analysis.

Indirect pulp treatment leaves the deepest decay to prevent a pulp exposure and seals it with a biocompatible material.

Iodoform stands for either Vitapex (Neo Dental International Inc, Burnaby, British Columbia, Canada) or Metapex (Meta Biomed LTD, Cheongju-si, Chungcheongbuk-do, South Korea) root canal filler, two identical proprietary brands containing an iodoform and calcium hydroxide.

Irreversible pulpitis and/or necrosis is a tooth that exhibits any one of the following clinical or radiographic findings: 1. history of unprovoked toothache; 2. sinus tract, soft tissue pathology, or gingival swelling not associated with periodontal disease; 3. abnormal mobility not associated with exfoliation; 4. radiographic furcation or periapical radiolucency; 5. external or internal radiographic root resorption. Diagnosis of irreversible pulpitis cannot be based solely on bleeding that cannot be controlled within five minutes.

Lasers are laser pulpotomies.

LSTR (lesion sterilization tissue repair) is a procedure for necrotic primary teeth that usually requires no instrumentation of the root canals or filling of the canals but instead includes placement of an antibiotic mixture in the pulp chamber to disinfect the root canals.

mm is a millimeter.

MTA is a mineral trioxide aggregate pulpotomy.

NaOCl (sodium hypochlorite) or common household bleach in one to five percent concentration or as used in the decision tree is a sodium hypochlorite pulpotomy.

NNT (number needed to treat) is the average number of teeth needed to be treated with one pulp treatment method to prevent one failure compared to the alternate treatment method.

Nonrestorable primary tooth is where the root(s) and/or crown has extensive resorption or destruction from caries or trauma or the tooth has a very poor prognosis and is not considered a candidate for non-vital pulp therapy.

Normal pulp is a tooth without reversible or irreversible pulpitis.

NRS is a nonrandomized observational study, and NRSs is the plural.

Pulpectomy is a root canal procedure for primary teeth with irreversible pulpitis or necrotic pulp resulting from caries or trauma in which the root canals are instrumented with files, irrigated, and filled with a resorbable material.

Pulpotomy is for pulp exposures after caries removal and the entire coronal pulp is removed and treated with various techniques or medicaments.

RCT is a randomized clinical trial, and RCTs is the plural.

Reversible pulpitis is the pulpal diagnosis for a tooth without signs or symptoms of irreversible pulpitis but that has provoked pain from eating for a short duration (5-10 minutes).

ROB (risk of bias) is an assessment of any deviations in the estimate of the intervention's results.

SR is the AAPD's systematic review on non-vital pulp therapies.¹

SSC is a stainless steel crown, and SSCs is the plural.

Success in this guideline refers to the overall success of teeth that show both clinical and radiographic success simultaneously after pulp treatment.

The AAPD **Workgroup (WG)** consisted of seven pediatric dentists nominated by the AAPD to perform a systematic review.

Traditional 3Mix is typically a mixture of three antibiotics (minocycline, metronidazole, and ciprofloxacin) blended in a propylene glycol base and used in LSTR treatment.

ZO/iodoform/CH (zinc oxide/iodoform/calcium hydroxide) root canal filler stands for Endoflas (Sanlor Laboratories, Miami, Fla., USA), which is a proprietary brand containing iodoform, zinc oxide, and calcium hydroxide.

ZOE root canal filler stands for a mixture of zinc oxide powder and the liquid eugenol.

(anterior or posterior), history of trauma, type or timing of final restoration placement, method of root length determination, smear layer removal, or number of treatment visits to complete the pulpectomy. Antibiotic mixtures used in LSTR should not include tetracycline since evidence shows that alternate antibiotic mixtures performed better than tetracyclines. Extraction is indicated for a nonrestorable tooth whose root(s) and/or crown has extensive resorption or destruction. In some cases, due to parent preferences or other reasons determined by the clinician and parent, extraction may be the best option even if the tooth is restorable. Regarding the quality of the evidence, all of the aforementioned recommendations were based on low or very low levels of evidence except two. The recommendations regarding rotary versus hand instrumentation of root canals and LSTR for teeth with root resorption had moderate levels of evidence. The quality of evidence was not assessed on extractions of non-restorable teeth. Future trials are needed to further evaluate which non-vital treatments are effective with follow-up periods of a minimum of two years.

Exceptions to the guideline recommendations. Regarding exceptions to the guideline recommendations, treatment plans may have to be altered from the Figure decision tree's recommendations due to a child's ability to cooperate, complex medical conditions, inability to achieve local anesthesia of the tooth, limited oral opening, severe gag reflex, facial swelling, oral pain with an unclear diagnosis, complications from prior pulp therapy, or concurrent periodontal problems. Also, parent and patient preferences, age, and cost of treatment may alter treatment decisions that may not conform to this decision tree or guideline.

Scope and purpose

The American Academy of Pediatric Dentistry (AAPD) intends this guideline to aid clinicians in optimizing patient care when choosing pulp therapies for treating children with non-vital or irreversibly inflamed primary teeth. The pulp diagnosis is based on symptoms as well as clinical and radiographic signs. Carious or traumatized primary teeth diagnosed with irreversible pulpitis or necrotic pulp can be treated with non-vital pulp therapies or extraction. Currently, there are two non-vital pulp therapies for primary teeth: (1) conventional pulpectomy and (2) lesion sterilization tissue repair (LSTR). For this guideline, the overall (combined clinical and radiographic) success of pulpectomy and LSTR was evaluated. The influence of various factors, such as the number of visits, root length determination method, instrumentation technique, irrigation, obturation (quality, techniques, and materials), and removal of the smear layer were evaluated for the overall success of conventional pulpectomy, which was also compared to LSTR in primary teeth with and without preoperative root resorption. In addition, reported adverse events such as pain were reviewed for this guideline.

The current recommendation supersedes the section on "Non-vital pulp treatment for primary teeth diagnosed with irreversible or necrotic pulp" in the AAPD best practices on pulp therapy for primary and immature permanent teeth²; however, it does not apply to pulp therapy for immature permanent teeth or pulp therapy for primary teeth with traumatic injuries.

Clinical questions addressed. The AAPD Workgroup (WG) used the Population, Intervention, Control, and Outcome (PICO) formulation to develop the following clinical questions that will aid clinicians in the use of non-vital pulp therapies in primary teeth:

1. In primary teeth, how do we diagnose irreversible pulpitis/pulp necrosis?

2. In non-vital primary teeth, when should a clinician choose extraction over non-vital pulp therapy?
3. In non-vital primary teeth, does pulpectomy have better long-term success in teeth with or without root resorption?
 - a) In primary teeth with no root resorption needing non-vital pulp therapy, how does the success of LSTR compare to conventional pulpectomy?
 - b) In primary teeth with significant root resorption (external greater than one millimeter (mm) and/or internal) needing non-vital pulp therapy, how does the success of LSTR compare to conventional pulpectomy?
4. In primary teeth treated with pulpectomy, what factors influence success?
 - a) In primary teeth treated with pulpectomy, does the number of treatment visits influence success?
 - b) In primary teeth treated with pulpectomy, does the method of root length determination influence success?
 - c) In primary teeth treated with pulpectomy, does the instrumentation (hand instruments versus rotary) technique influence time of treatment, quality of fill, and success?
 - d) In primary teeth treated with pulpectomy, does the removal of the smear layer influence success?
- e) In primary teeth treated with pulpectomy, does the choice of irrigants influence success?
- f) In primary teeth treated with pulpectomy, does the choice of obturation material influence success?
- g) In primary teeth treated with non-vital pulp therapy, does the timing and/or type of final restoration influence success?
- h) In primary teeth treated with pulpectomy, does the obturation technique (syringe, Lentulo, hand pluggers) influence the quality of fill and success?
- i) In primary teeth treated with pulpectomy, does tooth type (incisor, primary first molar, primary second molar) influence success?
- j) In teeth that are necrotic as a result of trauma, is pulpectomy successful?
5. In primary teeth treated with pulpectomy, does the type of isolation technique influence success?
6. In primary teeth treated with LSTR, what factors influence success?
 - a) When doing LSTR, how does traditional 3Mix (with tetracycline) compare to alternate 3Mix (without tetracycline)?
 - b) When doing LSTR, should the root canals be filed or broached?
7. What are the adverse events associated with non-vital pulp therapy in primary teeth?

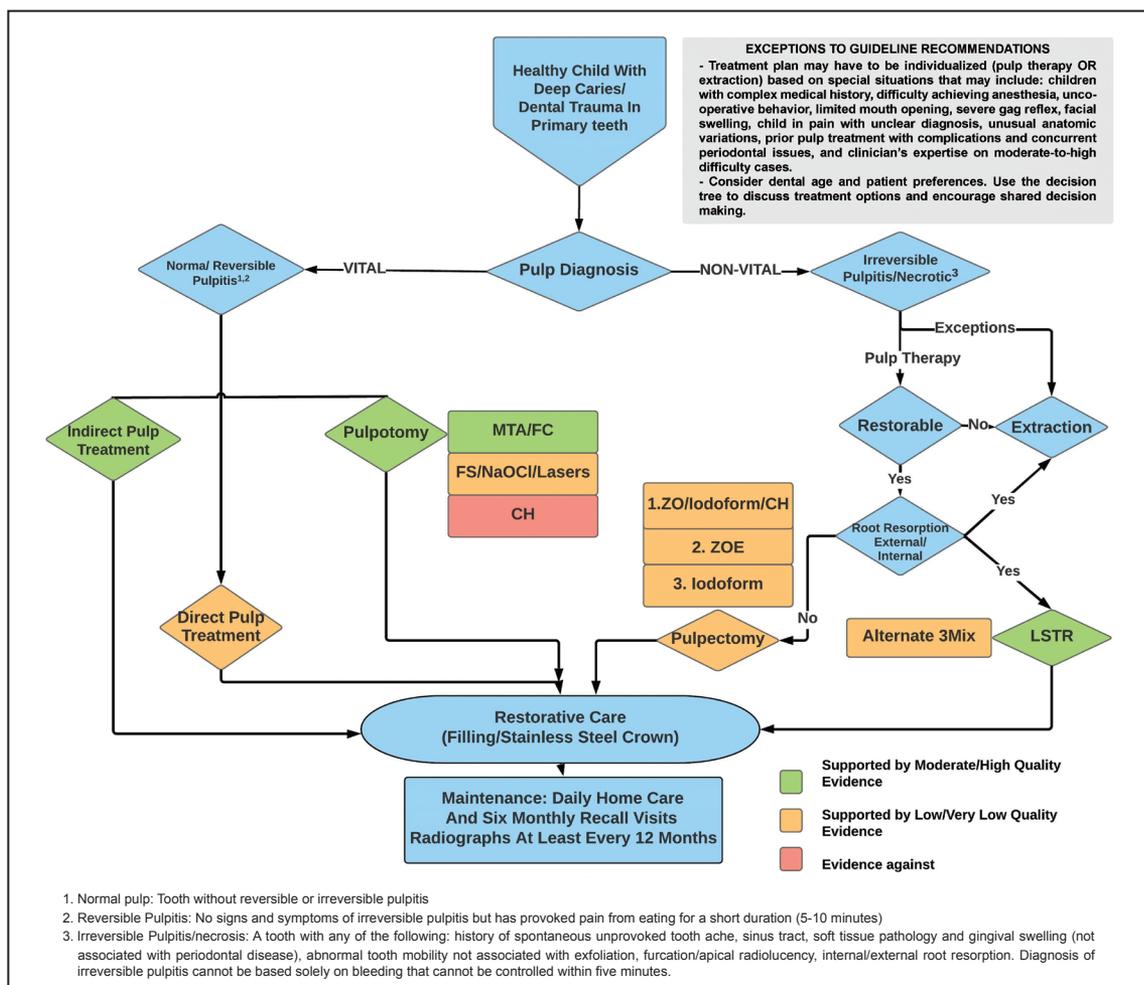


Figure. Guideline decision tree recommendations. Abbreviations in figure, see Glossary of Terms and Abbreviations.

Methods

The AAPD previously published best practices² on non-vital pulp therapy entitled “Pulp Therapy for Primary and Immature Permanent Teeth,” which was last revised in 2019. Evidence from a systematic review and meta-analysis of non-vital pulp therapy for primary teeth,¹ published with this guideline, is the basis for the current guideline’s recommendations.

Search strategy and evidence inclusion criteria. It was decided a priori to use the AAPD’s systematic review (SR) on non-vital pulp therapies.¹ The WG used multiple literature searches in PubMed®/MEDLINE, Embase®, Cochrane Central Register of Controlled Trials, and trial databases to identify randomized controlled trials (RCTs) and systematic reviews addressing peripheral issues not covered by the review, such as patient preferences and impact of cost. The search strategy was updated by one of the authors. Title, abstract, and full-text review of studies was done in duplicate independently by some WG members. They extracted the data and performed the risk of bias assessment (ROB) and meta-analyses.

Assessment of the evidence. This guideline is based on the SR¹ that assessed the quality of the evidence using the Grades of Recommendation Assessment, Development, and Evaluation (GRADE)³⁻⁵ approach.

Weaknesses of this guideline are inherent to the limitations found in the SR upon which this guideline is based. Limitations include failure to review non-English language studies other than those in Spanish, Portuguese, and Chinese, and the recommendations are based on combined data from studies of different risks of bias.

Formulation of the recommendations. The WG evaluated and voted on the level of certainty of the evidence using the GRADE approach. The GRADE approach recognizes the evidence quality and certainty as high, moderate, low, and very low^{4,5} based on serious or very serious issues, including the ROB, imprecision, inconsistency, indirectness of evidence, and publication bias. To formulate the recommendations, the WG used an evidence-to-decision framework, including domains such as priority of the problem, certainty in the evidence, balance between desirable and undesirable consequences, and patients’ values and preferences. The strength of a recommendation was assessed to be either strong or conditional, which presents different implications for patients, clinicians, and policy (Table 1).

The guidelines were formulated via teleconferences, in-person meetings, and online forum discussions with members of the WG. The WG members discussed all recommendations and issues surrounding the topic under review, and all significant topics such as recommendations were voted upon anonymously.

Understanding the recommendations. These clinical practice guidelines provide recommendations for non-vital pulp therapies in primary teeth. GRADE rates the strength of a recommendation as either strong or conditional in favor of or against an intervention. The strength of a recommendation presents different implications for patients, clinicians, and policymakers.

A strong recommendation in favor of the intervention implies the WG is confident that the desired benefits of the intervention outweigh any undesirable effects. A strong recommendation against the intervention implies the WG is confident that the undesired effects of the intervention outweigh any

Table 1. IMPLICATIONS OF STRONG AND CONDITIONAL RECOMMENDATIONS FOR DIFFERENT USERS OF GUIDELINES

	Strong recommendation	Conditional recommendation
For patients	Most individuals in this situation would want the recommended course of action; only a small proportion would not.	Most individuals in this situation would want the suggested course of action, but many would not.
For clinicians	Most individuals should receive the recommended course of action. Adherence to this recommendation according to the guideline could be used as a quality criterion or performance indicator. Formal decision aids are not likely to be needed to help individuals make decisions consistent with their values and preferences.	Recognize that different choices will be appropriate for different patients and that you must help each patient arrive at a management decision consistent with her or his values and preferences. Decision aids may well be useful in helping individuals making decisions consistent with their values and preferences. Clinicians should expect to spend more time with patients when working toward a decision.
For policymakers	The recommendation can be adapted as policy in most situations, including for the use of performance indicators.	Policymaking will require substantial debates and involvement of many stakeholders. Policies are also more likely to vary between regions. Performance indicators would have to focus on the fact that adequate deliberation about the management options has taken place.
Quality of evidence		
High	The American Academy of Pediatric Dentistry Workgroup is very confident that the true effect lies close to that of the estimate of the effect.	
Moderate	The American Academy of Pediatric Dentistry Workgroup is moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility it is substantially different.	
Low	The American Academy of Pediatric Dentistry Workgroup’s confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect.	
Very low	The American Academy of Pediatric Dentistry Workgroup has very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect.	
Quality of evidence is a continuum; any discrete categorization involves some degree of arbitrariness. Nevertheless, the advantages of simplicity, transparency, and vividness outweigh these limitations.		

potential benefits. A strong recommendation (for or against) means that, in most situations, clinicians may want to follow the WG's suggested course of action.

A conditional recommendation in favor indicates that, while there is appreciable uncertainty, the desired effects may outweigh the undesired effects of the intervention. A conditional recommendation against implies that, while there is appreciable uncertainty, the undesirable effects probably outweigh the potential benefits of the intervention. A conditional recommendation (for or against) means the WG recognizes that the clinician may want to follow the suggested course of action while being cognizant of the various other treatment choices, individual patient's circumstances, preferences, and values. A recommendation statement with "must" or "shall" indicates an imperative need and/or duty is an essential or indispensable item/mandatory; a recommendation with "should" indicates the recommended need and/or duty highly desirable, and a recommendation with "may" or "could" indicates freedom or liberty to follow a suggested alternative.⁶ Table 2 shows a summary of the recommendations included in this guideline.

Recommendations

Question 1. In primary teeth, how do we diagnose irreversible pulpitis/pulp necrosis?

Recommendation: The WG's review did not find any direct evidence to make a recommendation on the criteria to be used by clinicians for diagnosing irreversible pulpitis/pulp necrosis in primary teeth. It is suggested that a child's tooth with one or more clinical signs or symptoms of unprovoked toothache, sinus tract or other soft tissue pathology, gingival swelling not associated with periodontal disease, abnormal tooth mobility, or radiographically furcation or periapical radiolucency or external or internal root resorption be diagnosed as having irreversible pulpitis/pulp necrosis (Figure; see normal/reversible pulpitis and irreversible pulpitis/necrosis).

Summary of findings: The clinical signs and symptoms and radiographic findings suggestive of irreversible pulpitis/pulp necrosis in primary teeth were based on the selection criteria used by the studies included in the SR.¹ Diagnosis of irreversible pulpitis cannot be based solely on pulpal bleeding that cannot be controlled within five minutes.⁷

Remarks: According to the AAPD best practices for pulp therapy for primary and immature permanent teeth,² a tooth planned for pulpotomy where the hemorrhage cannot be "controlled with a damp cotton pellet applied for several minutes" exhibits signs of irreversible pulpitis. There is no reference for this statement. A recent study⁷ concluded that "controlling bleeding at the exposure site or canal orifices does not provide an accurate assessment of inflammation at the canal orifice and may be misleading for diagnosing vital pulp treatment in primary teeth with carious pulp exposure." Therefore, the inability to control pulpal hemorrhage after a few minutes may not solely be a reliable indicator of irreversible pulpitis.

Question 2. In non-vital primary teeth, when should a clinician choose extraction over non-vital pulp therapy?

Recommendation: The WG did not find any direct evidence to make a recommendation on the criteria to be used by clinicians for choosing extraction over non-vital pulp therapy in non-vital primary teeth. It is suggested that, for teeth deemed nonrestorable or when the patient has one or more exceptions to the guideline recommendations stated previously in this guideline and Figure, the treatment of choice may be extraction.

Summary of findings: The AAPD's SR¹ stated the RCT articles on pulpectomy and LSTR showed nonrestorable teeth were extracted. Teeth were not considered for pulpectomy or LSTR if they had an inadequate crown or extensive root structure resorption and were not restorable.

Question 3. In non-vital primary teeth, does pulpectomy have better long-term success in teeth with or without root resorption?

Recommendation: Evidence suggests that pulpectomy is a viable long-term treatment for non-vital primary teeth without root resorption compared to those with root resorption. Therefore, pulpectomy should be considered for non-vital primary teeth without preoperative root resorption. (*Conditional recommendation, very low quality of evidence—12 months; conditional recommendation, very low quality of evidence—24 months.*)

Summary of findings: Studies on pulpectomy success of 12 months or longer, irrespective of the root canal filler type or method of obturation, were evaluated in the SR¹ using a meta-analysis comparing teeth with and without root resorption. Those without root resorption had statistically significant higher success (89 percent) compared to those with root resorption (47 percent). The quality of the evidence for this result was very low, according to the GRADE at 12 months, due to the very serious heterogeneity seen in the I² statistic and very serious indirectness due to the indirect comparison.

The 24-month findings were similar to the 12-month findings, but there was only one study with root resorption and one without root resorption. Therefore, a meta-analysis of RCTs was not computed. A meta-analysis of pulpectomy studies with 24-month follow-up was conducted for combined RCT non-randomized observational study (NRS) success rates in the SR.¹ There was a significant difference between the teeth with or without preoperative root resorption. Teeth with resorption had significantly less success (59 percent) compared to teeth without resorption (88 percent). The quality of the evidence for this result was very low according to GRADE at 24 months, due to high ROB and very serious indirectness.

Remarks: For longer periods (24 to 60 months) from RCT and NRS articles, pulpectomy success in teeth without preoperative root resorption from the SR¹ had higher success (84 to 90 percent) versus teeth with preoperative root resorption (59 to 69 percent).

Question 3a. In primary teeth with no root resorption needing non-vital pulp therapy, how does the success of LSTR compare to conventional pulpectomy?

Recommendation: Pulpectomy success was higher than LSTR for teeth without preoperative root resorption, indicating it should be preferred over LSTR in these teeth. (*Conditional recommendation, low quality of evidence.*)

Summary of findings: For teeth with no external or internal root resorption from direct comparison data, LSTR success was 65 percent compared to 92 percent for pulpectomy success. For this comparison, the meta-analysis favored pulpectomy, although the difference was not statistically different (relative risk [RR] equals 0.77; 95 percent confidence interval [95% CI] equals 0.56 to 1.05).¹ The NNT equals five, which means that after 12 months one failure may be prevented for every five teeth using pulpectomy instead of LSTR. The quality of the evidence for this result was low, according to the GRADE at 12 months, due to a serious imprecision seen in the sample sizes and the serious heterogeneity seen in the I² statistic (measurement of inconsistency of the data included in the meta-analysis).

Table 2. SUMMARY OF CLINICAL RECOMMENDATIONS ON NON-VITAL PULP THERAPIES IN PRIMARY TEETH*

Clinical question	Recommendation	Quality of evidence (follow-up duration)	Strength of recommendation
1. In primary teeth, how do we diagnose irreversible pulpitis/pulp necrosis?	No evidence-based dentistry recommendation.		
2. In non-vital primary teeth, when should a clinician choose extraction over non-vital pulp therapy?	No evidence-based dentistry recommendation.		
3. In non-vital primary teeth, does pulpectomy have better long-term success in teeth with or without root resorption?	Pulpectomy is a viable long-term treatment for non-vital teeth without root resorption compared to those with root resorption. Therefore, pulpectomy should be considered for non-vital primary teeth without preoperative root resorption.	Very low (12 months) Very low (24 months)	Conditional Conditional
a) In primary teeth with no root resorption needing non-vital pulp therapy, how does the success of LSTR compare to conventional pulpectomy?	Pulpectomy success was higher than LSTR for teeth without preoperative root resorption, indicating it should be preferred over LSTR in these teeth.	Low (12 months)	Conditional
b) In primary teeth with significant root resorption (external greater than one mm and/or internal) needing non-vital pulp therapy, how does the success of LSTR compare to conventional pulpectomy?	If the clinician decides not to extract the tooth with significant preoperative root resorption, LSTR should be chosen over pulpectomy to save such teeth for up to 12-months, but if retained longer should be monitored with periodic clinical exams and radiographs at least every 12 months after doing LSTR.	Moderate (12 months)	Conditional
4. In primary teeth treated with pulpectomy, what factors influence success?			
a) In primary treated with pulpectomy, does the number of treatment visits influence success?	In primary teeth treated with pulpectomy the overall success after 12 months was not impacted by the number of visits; therefore, it is suggested that the clinicians may choose either one-visit or two-visit pulpectomy based on clinical expertise and individual circumstances.	Very low (12 months)	Conditional
b) In primary teeth treated with pulpectomy, does the method of root length determination influence success?	Clinicians may choose any of the methods (tactile, radiographs, apex locators) based on their clinical expertise and individual circumstances.	Very low	Conditional
c) In primary teeth treated with pulpectomy, does the instrumentation (hand instruments versus rotary) technique influence time of treatment, quality of fill, and success?	Rotary instrumentation time was significantly shorter than manual by approximately two minutes, but the two instrumentation methods had comparable successes while the occurrence of flush fills favored rotary. Considering these findings and the additional resources/training for rotary over manual instrumentation, clinicians may choose either method of instrumentation.	Moderate	Conditional
d) In primary teeth treated with pulpectomy, does the removal of the smear layer influence success?	No evidence-based dentistry recommendation.		
e) In primary teeth treated with pulpectomy, does the choice of irrigants influence success?	The choice of irrigants (sodium hypochlorite one to five percent, water/saline, or chlorhexidine) had no impact on pulpectomy success. Therefore, the clinician may choose any of these irrigation solutions based on their clinical expertise and individual circumstances.	Very low	Conditional

* Abbreviations in table, see Glossary of Terms and Abbreviations.

Question 3b. In primary teeth with significant root resorption (external greater than one mm and/or internal) needing non-vital pulp therapy, how does the success of LSTR compare to conventional pulpectomy?

Recommendation: If the clinician decides not to extract the tooth with significant preoperative root resorption, LSTR should be the choice over pulpectomy to save such teeth for up to 12 months, but if retained longer should be monitored

with periodic clinical exams and radiographs at least every 12 months after doing LSTR. (*Conditional recommendation, moderate quality of evidence.*)

Summary of findings: For teeth with external or internal root resorption from direct comparison data, the LSTR success rate was 76 percent compared to the pulpectomy success rate of 47 percent. This included teeth where the canals were filed or not before antibiotic placement for LSTR. The meta-analysis was

Table 2. CONTINUED*

Clinical question	Recommendation	Quality of evidence (follow-up duration)	Strength of recommendation
f) In primary teeth treated with pulpectomy, does the choice of obturation material influence success?	The evidence suggests that ZO/iodoform/CH and ZOE may be a better choice for pulpectomy success compared to iodoform at 18 months. The network analysis after 18 months showed that ZO/iodoform/CH ranked first followed by ZOE and then iodoform.	Very low (18 months)	Conditional
g) In primary teeth treated with non-vital pulp therapy, does the timing and/or type of final restoration influence success?	The 12-month data showed stainless steel crowns versus fillings had comparable success unaffected by the timing of when the final restoration was placed. The limited 24-month data suggests that the teeth restored with stainless steel crowns had better success than composites. Therefore, the clinician may choose the type and timing of restoration placement based on their clinical preference.	Very low	Conditional
h) In primary teeth treated with pulpectomy, does the obturation technique (syringe, Lentulo, hand pluggers) influence the quality of fill and success?	The quality of the fill (flush fill) and pulpectomy success using Lentulo spirals, hand pluggers, and syringes were not statistically different. The clinician may choose any of these obturation techniques based on clinical preference.	Very low	Conditional
i) In primary teeth treated with pulpectomy, does the tooth type (incisor, primary first molars, primary second molars) influence success?	No evidence-based dentistry recommendation.		
j) In teeth that are necrotic as a result of trauma, is pulpectomy successful?	No evidence-based dentistry recommendation.		
5. In primary teeth treated with pulpectomy, does the type of isolation technique influence success?	No evidence-based dentistry recommendation.		
6. In primary teeth treated with LSTR, what factors influence success?			
a) When doing LSTR, how does traditional 3Mix (with tetracycline) compare to alternate 3Mix (without tetracycline)?	Considering the significantly higher success of alternate 3Mix and the potential adverse effects of tetracycline in children, when doing LSTR clinicians should choose an alternate 3Mix (without tetracycline) over traditional 3Mix.	Very low	Conditional
b) When doing LSTR, should the root canals be filed or broached?	When doing LSTR, clinicians may choose whether or not to file/broach the canals since both methods were not significantly different in success.	Very low	Conditional
7. What are the adverse events associated with non-vital pulp therapy in primary teeth?	No evidence-based dentistry recommendation.		

* Abbreviations in table, see Glossary of Terms and Abbreviations.

significant ($P=0.001$), favoring LSTR¹ (RR equals 1.65; 95% CI equals 1.31 to 2.08). The NNT equals four, meaning one failure would be prevented for every four teeth using LSTR instead of pulpectomy. The quality of the evidence for this result was moderate, according to the GRADE at 12 months, due to the serious imprecision seen in the sample sizes.

Remarks: Qualitative data from prospective^{8,9} studies showed the combined 24-month LSTR success was 37 percent in these studies. The report from Grewal¹⁰ is a 36-month RCT; it found that LSTR treatment adversely affected the permanent tooth eruption due to interradicular bone loss and, in one case, caused an odontogenic keratocyst. Perhaps LSTR should be used only to save primary molars for up to 12 months to maintain space and then be monitored periodically.

Question 4. In primary teeth treated with pulpectomy, what factors influence success?

Question 4a. In primary teeth treated with pulpectomy, does the number of treatment visits influence success?

Recommendation: In primary teeth treated with pulpectomy, the overall success after 12 months was not impacted by the number of visits; therefore, it is suggested that clinicians may choose either a one-visit or two-visit pulpectomy based on clinical expertise and individual circumstances. (*Conditional recommendation, very low quality of evidence.*)

Summary of findings: The effect of whether one- or two-visit pulpectomy affected success was tested with meta-analyses in the SR.¹ For the one-visit group, the pooled success was 74 percent compared to 81 percent for the two-visit group. The difference between the groups was not significantly different.

The quality of the evidence for this finding was very low due to the very serious inconsistency in the I^2 statistic and the indirect comparison.

Question 4b. In primary teeth treated with pulpectomy, does the method of root length determination influence success?

Recommendation: Evidence suggests that clinicians may choose any of the root length determination methods (tactile, radiographs, apex locators) based on their clinical expertise and individual circumstances. (*Conditional recommendation, very low quality of evidence.*)

Summary of findings: The effect of whether the method of root length determination altered success was tested with meta-analyses in the SR.¹ For the studies that used an apex locator, the pooled success was 79 percent compared to 86 percent for those that used radiographs. The two methods were not significantly different ($P=0.28$). The quality of the evidence for this finding was very low due to the very serious inconsistency in the I^2 statistic and indirect comparison.

Remarks: There was one in vivo study¹¹ of single-rooted primary anterior teeth using an apex locator, radiographs, and tactile feel of the apex in the mouth to the actual length of the tooth after it was extracted. This article did not evaluate pulpectomy success. Of the 22 teeth without root resorption, the apex locator and radiographs mean length deviation from the actual mean length of 15 mm was insignificant while the tactile feel method was one mm significantly shorter in the same teeth. In 29 teeth with apical root resorption, the mean lengths for tactile feel, radiographic, and apex locator were 0.1 mm shorter than the actual length. Two clinical NRSs^{12,13} used tactile feel for their primary tooth pulpectomies. They had success data that could be computed for 21 months on primary molars (96.6 percent success; 513 out of 531) and 46 months (93.8 percent; 485 out of 517).

Question 4c. In primary teeth treated with pulpectomy, does the instrumentation (hand instruments versus rotary) technique influence time of treatment, quality of fill, and success?

Recommendation: Rotary instrumentation time was significantly shorter than manual instrumentation time by approximately two minutes, but the two instrumentation methods had comparable successes while the occurrence of flush fills (a root canal filled to the apex) favored rotary. Considering these findings and the additional resources/training for rotary over manual instrumentation, clinicians may choose either method of instrumentation. (*Conditional recommendation, moderate of evidence.*)

Summary of findings: manual versus rotary canal preparation time. The meta-analysis comparing rotary to manual canal filing showed a significant difference favoring rotary filing, which was approximately two minutes faster than manual filing (mean difference [MD] equals -126; 95% CI equals -167 to -85; $P<0.0001$).¹ The quality of the evidence for this result was high according to the GRADE. Although there was heterogeneity seen in the I^2 statistic, this was only due to how much faster rotary canal preparation was compared to manual preparation. Only one clinical study¹⁴ compared manual versus rotary filing after 24 months, and there was no significant difference in the two groups' pulpectomy success. The antibacterial observational study by Subramaniam¹⁵ evaluating manual versus rotary canal preparation showed no difference in bacterial reduction.

Manual versus rotary optimum (flush) filling outcome. The meta-analysis favored the use of rotary filing compared to manual root canal filing for achieving a flush apical fill. Although there was no statistical difference ($P=0.07$), the use of rotary filing had 32 percent more flush fills than those using manual filing.¹ The NNT equals six, meaning that, after doing six pulpectomies with manual filing, one more flush fill may have occurred using rotary compared to manual. The quality of the evidence for this result was moderate according to the GRADE due to serious heterogeneity seen in the I^2 statistic.

Remarks: Rotary instrumentation required less time and involved less dentin removal and more uniform root canal preparation.¹⁶ Since many primary tooth root canals are ribbon-shaped and rotary instruments are centered in root canals, rotary instrumentation may potentially leave behind infected tissue in unclear areas in fins and isthmuses; also, additional hand instrumentation with copious irrigation may be needed to remove the remnant tissues.¹⁷ The higher cost of a rotary system and the need for training to learn the technique are additional factors to consider.

Question 4d. In primary teeth treated with pulpectomy, does the removal of the smear layer influence success?

Recommendation: The WG did not find adequate evidence to make a recommendation on the influence of smear layer removal on the success of the pulpectomy. In the SR,¹ primary tooth pulpectomy success did not seem to depend on whether or not the smear layer was removed. Therefore, it is suggested that the clinician choose either way of managing the smear layer based on clinical expertise and individual circumstances.

Summary of findings: The effect of smear layer removal in primary teeth was evaluated in two RCTs in the SR.¹ They could not be evaluated statistically since one was a 24-month study and the other a 36-month study. The 36-month study showed, with smear layer removal, a pulpectomy success rate of 82 percent (14 out of 17) versus 88 percent (15 out of 17) without smear layer removal, and the 24 months study had similar success rates that also were not statistically different. Smear layer removal for pulpectomy in primary teeth does not seem to alter its success.

Remarks: The smear layer is an accumulation of dentin and pulpal debris formed on the root canal walls during instrumentation for a pulpectomy by rotary or manual filing. Its removal possibly allows the root canal filler to adapt better to the canal walls, but the smear layer may occlude the dentin tubules and prevent bacteria and toxin penetration.

Question 4e. In primary teeth treated with pulpectomy, does the choice of irrigants influence success?

Recommendation: The choice of irrigants (sodium hypochlorite one to five percent, water/saline, or chlorhexidine) had no impact on pulpectomy success. Therefore, the clinicians may choose any of these irrigation solutions based on their clinical expertise and individual circumstances. (*Conditional recommendation, very low quality of evidence.*)

Summary of findings: There were three studies in the SR¹ that only used sodium hypochlorite (NaOCl) as the canal irrigation method. Three other studies used NaOCl and either saline or distilled water during the canal preparation or as the final irrigation solution. The effect of whether the type of irrigation altered success was tested with meta-analyses. For the studies that used NaOCl, the pooled success was 80 percent

versus 81 percent for those that used NaOCl and saline and/or distilled water. The difference between the groups was not significant.¹ The quality of the evidence for this result was very low according to the GRADE due to the serious heterogeneity in the I^2 and the indirectness of the comparisons.

Remarks: The SR¹ investigated irrigation of root canals using water/saline, NaOCl, and chlorhexidine on pulpectomy success after 12 months. This data came from a mixture of RCTs and NRSs with different pulpectomy fillers and methods. The articles could not be appropriately grouped to conduct direct comparisons of the irrigation methods. This data could only compute overall pulpectomy success using the three irrigation solutions. The water/saline group evaluated eight studies, which had a pulpectomy success rate of 81 percent (341 out of 421). The success rate of the pulpectomies from 12 studies in the NaOCl group was 89 percent (1,370 out of 1,538). For the three studies in the chlorhexidine group, the success rate of the pulpectomies was 87 percent (162 out of 186).

Question 4f. In primary teeth treated with pulpectomy, does the choice of obturation material influence success?

Recommendation: The evidence suggests that zinc oxide/iodoform/calcium hydroxide (ZO/iodoform/CH) and zinc oxide eugenol (ZOE) may be a better choices for pulpectomy success compared to iodoform at 18 months. (*Conditional recommendation, very low quality of evidence.*) The network analysis after 18 months showed that ZO/iodoform/CH ranked first, ZOE second, and iodoform last.

Summary of findings: pulpectomy root canal fillers—ZOE versus iodoform pulpectomy success after 18 months. The meta-analysis showed no significant difference between the success rates for ZOE (92 percent) and iodoform (71 percent) at 18 months.¹ The ZOE success rate was 14 percent better than iodoform; the NNT equals 12, indicating that, after doing 12 pulpectomies, one failure may have been prevented using ZOE compared to iodoform. The quality of the evidence for this result was very low, according to the GRADE at 18 months, due to the very serious heterogeneity in the I^2 statistic, high ROB, and sample size issues.

ZOE versus ZO/iodoform/CH success 18 months. The ZO/iodoform/CH success rate was 93 percent versus 89 percent for ZOE at 18 months, and the meta-analysis showed no significant difference.¹ The quality of the evidence for this result was low, according to the GRADE at 18 months, due to the high ROB, serious imprecision seen in the sample sizes in each arm.

ZO/iodoform/CH versus iodoform success 18 months. The ZO/iodoform/CH success rate was 93 percent compared to 63 percent for iodoform at 18 months, and the meta-analysis showed no significant difference.¹ The quality of the evidence for this result was very low, according to the GRADE at 18 months, due to the high ROB, serious imprecision seen in the sample sizes in each arm, and the very serious heterogeneity in the I^2 statistic. The nonsignificant NNT equals seven means after 18 months, meaning you may prevent one failure after seven pulpectomies using ZO/iodoform/CH instead of iodoform.

Remarks: The meta-analysis¹ at 18 months showed a significant difference ($P < 0.001$) between the success of ZO/iodoform/CH and the Vitapex brand of iodoform (RR equals 1.73; 95% CI equals 1.34 to 2.33). The Metapex brand of iodoform showed no significant difference in success compared to ZO/iodoform/CH (RR equals 1.27; 95% CI equals 0.78 to 1.12).

Network analysis: The objective of a network meta-analysis is to combine both the direct and indirect evidence across all studies. The network meta-analysis also ranks the effectiveness of the studied interventions. The 18-month network analysis of pulpectomy filler success ranked ZO/iodoform/CH first, ZOE second, and iodoform worst.¹ Regarding the cumulative probability percentages of rankings, ZO/iodoform/CH and ZOE were markedly better than iodoform. From the 18-month direct comparison data, ZO/iodoform/CH or ZOE appeared to maintain an 18-month success rate near or above 90 percent over time while iodoform success decreased to 71 percent or lower.

ZOE and ZO/iodoform/CH versus calcium hydroxide success 12 and 18 months. Two RCTs compared ZOE pulpectomy success to different CH brands at 12 months. The ZOE success rate was 99 percent compared to the CH success rate of 74 percent. The meta-analysis showed a nonsignificant difference between the success rates of ZOE (99 percent) and one CH brand (74 percent).¹ In the SR¹ sensitivity analysis, the other CH brand meta-analysis result was statistically different ($P < 0.0001$) The NNT equals four, meaning after 12 months one failure would be prevented using a ZOE pulpectomy instead of CH. The quality of the evidence for this result was low, according to the GRADE at 12 months, due to the high ROB and serious imprecision in the sample sizes.

The SR¹ found only one RCT at 18 months comparing ZOE to CH. The ZOE success rate was 100 percent (40 out of 40) compared to the CH success of 85 percent (34 out of 40). The same RCT had different arms of CH compared to ZO/iodoform/CH success. There was no valid comparison using these pulpectomy success rates at 12 or 18 months; therefore, CH was not included in the network analysis.

Question 4g. In primary teeth treated with non-vital pulp therapy, does the timing and/or type of final restoration influence success?

Recommendation: The 12-month data showed stainless steel crowns (SSCs) versus fillings had comparable success unaffected by the timing of when the final restoration was placed. The limited 24-month data suggests that teeth restored with SSCs had better success than composites. Therefore, the clinician may choose the type and timing of restoration placement based on their clinical preference. (*Conditional recommendation, very low quality of evidence.*)

Summary of findings: type of final restoration. The SR¹ found 15 studies treated teeth with SSCs and five other studies treated teeth with a filling (composite or amalgam). A meta-analysis tested for any 12-month pulpectomy success differences between the two groups and found no significant difference. The quality of the evidence for this result was very low, according to the GRADE, due to the very serious heterogeneity in the I^2 and indirect comparison. The SR¹ reported on four NRSs with 24-month data on the type of restoration and success using SSCs and two that used composites. These articles were a mixture of RCTs and observational studies. They showed 24-month pulpectomy success for SSC was 90 percent and for composite was 77 percent.

Timing of final restoration. The SR¹ found 12 studies that treated the teeth on the same day as the pulpectomy and 10 studies that treated the teeth at a later date. For treatment the same day, the pulpectomy success after 12 months was 82 percent compared to 83 percent for placing the restoration at a

later date (one day to one or more weeks later). The difference between the groups was not significant. The quality of the evidence for this result was very low, according to the GRADE, due to the very serious heterogeneity in the I^2 and indirect comparison.

Question 4h. In primary teeth treated with pulpectomy, does the obturation technique (syringe, Lentulo, hand pluggers) influence the quality of fill and success?

Recommendation: The quality of the fill (flush fill) and pulpectomy success using Lentulo spirals, hand pluggers, and syringes were not statistically different. The clinicians may choose any of these obturation techniques based on their clinical preference. (*Conditional recommendation, very low quality of evidence.*)

Summary of findings: quality of pulpectomy fill. The SR¹ used a forest plot and compared the pulpectomy data on flush fills (a root canal filled to the apex) from nine studies using Lentulo spirals, five using hand pluggers, and nine using syringes. Using a Lentulo spiral resulted in 63 percent flush fills versus 48 percent with a hand plugger and 62 percent with a syringe. There was no significant difference for the three methods of obturation achieving pulpectomy flush fills. This was a very low quality of evidence due to serious inconsistency in the I^2 statistic and indirectness of evidence.

Obturation method and pulpectomy success. The SR¹ used a forest plot to compare the pulpectomy success using Lentulos from 12 studies, six using hand pluggers, and seven using syringes. Using Lentulos resulted in 91 percent success versus 87 percent using hand pluggers and 87 percent with syringes after 12 months. There was no significant difference in the three methods of obturation achieving success. The evidence consists of indirect comparisons from various types of study designs (RCTs and observational studies) and different follow-up times. This is a very low quality of evidence due to the very serious heterogeneity in the I^2 statistic and indirect comparisons of evidence.

The SR¹ used five RCT studies that directly compared pulpectomy success using Lentulo fills versus syringe fills after 12 months of follow-up. The meta-analysis showed no significant difference in these success rates. This is a very low quality of evidence due to the high ROB in some studies and very serious inconsistency in the I^2 statistic.

Remarks: The overfilling of the canals appears to be related to a lower success for pulpectomy. The data from various RCT and retrospective studies¹⁸⁻²² show overfilling the root canals in primary teeth tended to result in lowered success. The type of obturation technique (hand plugger, Lentulo, syringe delivery tip) all produce voids when evaluated in vitro and some techniques may cause more overfills (Lentulo) than others.²³ There were not enough clinical studies to evaluate these effects.

Question 4i. In primary teeth treated with pulpectomy, does the tooth type (incisor, primary first molar, primary second molar) influence success?

Recommendation: The WG did not find adequate evidence to make a recommendation on the influence of tooth type on success. Pulpectomy success rates from 13 to 36 months do not seem to be altered if a molar versus an incisor is treated due to caries. In addition, the pulpectomy success rates for primary first molars and primary second molars seem to be comparable.

Summary of findings: The SR¹ used 10 studies to report the success rate of the particular primary tooth treated with pulpectomy and the follow-up time. Three RCTs had a 12- to 36-month follow-up and seven NRSs had a follow-up from six to 91 months. For teeth treated due to caries and followed a minimum of 12 months, the incisor success rate was 87 percent (144 out of 166) and the molar success rate was 89 percent (138 out of 155). The success rates for primary first molars versus second molars were nearly the same (91 percent [51 out of 56] and 90 percent [69 out of 77], respectively). No statistical comparison could be made since the evidence consisted of indirect comparisons from various types of study designs and follow-ups. No GRADE assessment of the quality of this evidence was possible.

Remarks: The SR¹ data indicated tooth type did not appear to affect the success rates of primary incisor pulpectomies versus primary molar pulpectomies after 12 months. The success rate for primary incisors was 87 percent (144 out of 166) if treated due to caries versus 89 percent (138 out of 155) for primary molars.

Question 4J. In incisors that are necrotic as a result of trauma, is pulpectomy successful?

Recommendation: The WG did not find adequate evidence to make a recommendation on the influence of trauma on success. The pulpectomy success rate in incisors treated due to trauma or caries was comparable. It does not appear that pulpectomy success was adversely affected if treated for trauma or caries unless the tooth was retraumatized.

Summary of findings: The SR¹ found 10 studies that assessed the success of pulpectomy after trauma or caries. The success rate of traumatized primary anterior teeth pulpectomy after a minimum of 12 months was 77 percent (122 out of 159) versus 87 percent (144 out of 166) for primary incisors with caries. No statistical comparison could be made since the evidence consisted of indirect comparisons from various types of study designs and follow-ups. No GRADE assessment of the quality of this evidence was possible.

Remarks: From this data,¹ incisor pulpectomy success rates do not appear to be much different if treated due to trauma or caries after 12 months. In one RCT study,²⁴ trauma did not decrease the success of an incisor pulpectomy unless the incisor was retraumatized; then pulpectomy success decreased significantly to 41 percent.

Question 5. In primary teeth treated with pulpectomy, does the type of isolation technique influence success?

Recommendation: The WG did not find evidence to make a recommendation on the type of isolation technique influencing success. The use of a rubber dam for non-vital procedures is critical to maintaining isolation from saliva, blood, and other contaminants.

Summary of findings: All the studies except five used a rubber dam.¹ The five that did not use a rubber dam did not have usable data to evaluate.

Remarks: The use of a rubber dam is accepted as the standard of care when performing non-vital pulp therapy. It may be unethical to perform a study comparing with and without use of a rubber dam.

Question 6. In primary teeth treated with LSTR what factors influence success?

Question 6a. When doing LSTR, how does traditional 3Mix (with tetracycline) compare to alternate 3Mix (without tetracycline)?

Recommendation: Considering the significantly higher success of alternate 3Mix and the potential adverse effects of tetracycline in children, when doing LSTR clinicians should choose an alternate 3Mix (without tetracycline) over traditional 3Mix. (*Conditional recommendation, very low quality of evidence.*)

Summary of findings: The SR¹ reported the 12-month data of success from nine RCT studies comparing LSTR using 3Mix with minocycline to five LSTR studies using an alternate antibiotic mixture where a tetracycline was not included. There was significantly less success statistically (56 percent) using 3-Mix with a tetracycline versus 3-Mix without tetracycline (76 percent). The quality of the evidence for this result was very low, according to the GRADE at 12 months due to the very serious heterogeneity seen in the I² statistic, and very serious indirectness due to the indirect comparison.

Remarks: There also was in vitro evidence on this finding. Rafatjou²⁵ found that the combination of clindamycin, metronidazole, and ciprofloxacin was as effective as the combination of minocycline, metronidazole, and ciprofloxacin, with no significant difference observed in reducing mean bacterial colony counts.

Question 6b. When doing LSTR, should the root canals be filed or broached?

Recommendation: When doing LSTR, clinicians may choose whether or not to file/broach the canals since the success rate for each method was not significantly different. (*Conditional recommendation, very low quality of evidence.*)

Summary of findings: The SR¹ reported on 11 RCT and NRS studies of LSTR treatment with 12-month results where the canals were not filed or broached before placing the antibiotic paste. A meta-analysis compared these 11 studies to four RCT articles on LSTR where the canals were filed and/or broached before the triple antibiotic paste was placed. There was no significant difference in success rate when the canals were filed or broached before the antibiotic paste placement (72 percent) versus when the canals were not filed or broached before the antibiotic paste was placed (62 percent). The quality of the evidence for this result was very low, according to the GRADE at 12 months, due to the serious heterogeneity seen in the I² statistic and very serious indirectness due to the indirect comparison.

Question 7. What are the adverse events associated with non-vital pulp therapy in primary teeth?

Recommendation: The WG did not find adequate evidence to make a recommendation on adverse events after pulpectomy. Moderate to severe pain after 24 hours from a pulpectomy procedure appears to be rare. Enamel defects in the succedaneous tooth replacing a tooth with a pulpectomy seems to be rare, but retained ZOE filler after pulpectomy exfoliation is not an uncommon occurrence. LSTR treatment after 36 months from one report¹⁰ described intraradicular bone loss affecting the permanent tooth. Clinicians should evaluate non-vital pulp treatments for success and adverse events clinically and radiographically at least every 12 months.

Summary of findings: pulpectomy filler resorption. The qualitative data from the SR¹ on filler resorption from six RCTs and NRSs indicated ZOE resorbs slower than the primary tooth root in some cases. This may cause the permanent tooth's path of eruption to be deflected and may result in anterior crossbite for incisors. The iodoform fillers seemed to resorb at a faster rate than the root, resulting in the pulpectomy looking more like a pulpotomy after 12 to 18 months. Seven studies in the SR¹ found that, if the filler is extruded beyond the apex, iodoform fillers all seem to resorb but ZOE resorbs slowly and can take years to resorb. The qualitative data reported that teeth filled with ZOE for the pulpectomy had all or part of the filler retained in 138 out of 448 teeth (31 percent) based on data from 13 RCTs and NRSs.

Exfoliation after non-vital pulp treatment. The SR¹ reported that, based on Trairatvorakul's⁸ LSTR study, six out of eight teeth exhibit abnormal exfoliation after a two-year follow-up. Grewal's study¹⁰ was the longest LSTR follow-up (36 months). It showed that LSTR-treated teeth did not resorb, unlike untreated contralateral teeth. The SR¹ combined nine studies on pulpectomy, including RCTs and NRSs showing 76 out of 317 (24 percent) pulpectomy-treated teeth had early exfoliation, and 29 out of 319 (nine percent) were overretained compared to contralateral teeth.

Problems from non-vital treatment in primary teeth on the succedaneous teeth. The SR¹ found only one LSTR study²⁶ reporting an enamel defect in one out of 71 (one percent) succedaneous teeth. From the SR,¹ qualitative data on pulpectomy in five NRSs reported on the presence of enamel defects in succedaneous teeth. The studies indicated the pulpectomy procedure did not cause enamel defects in the succedaneous tooth. Instead, defects were related to the age²⁷ of the child (younger than 4.6 years) when the tooth became infected, excessive preoperative root resorption,²⁸ or trauma.¹⁸ One pulpectomy study²⁷ involving 103 succedaneous teeth found only seven out of the 103 (6.8 percent) had a small enamel defect. Grewal¹⁰ reported that LSTR teeth followed-up for 36 months were overretained compared to the conventional pulpectomy treatment group, and some LSTR teeth were associated with interradicular bone loss surrounding the crown of a permanent successor.

Pain. The SR¹ reported that qualitative data on postoperative pain after the first 24 to 48 hours was only associated when a non-vital treatment failed. The SR¹ could only identify three studies on immediate postoperative pain during the first 24 hours after pulpectomy. Taking the three studies²⁹⁻³¹ together, regardless of the different variables, the SR¹ categorized the results into no pain, mild pain, and moderate to severe pain in three time intervals: six, 12, and 24 hours posttreatment. The results at 24 hours showed the following: children having no pain (80 percent; 208 out of 261); children with mild pain (12 percent; 31 out of 261); and children with moderate to severe pain (eight percent; 22 out of 261). Severe pain from the pulpectomy procedure did not appear to be a major occurrence.

Research considerations

For non-vital primary tooth pulp treatment, there are various criteria used to grade success. The use of a consistent set of standards to report treatment success would help future systematic reviewers compare results. A furcation radiolucency should decrease after six months or totally resolve to be assessed a success. A static or unchanged radiolucency means the infection is still present but not causing clinical symptoms.

The WG observed problems with some studies in the process of compiling the SR.¹ Authors should ensure their flow diagrams match their results and data in their tables. Also, reviewers of articles should insist that data they are reviewing matches so that future systematic reviewers can extract valid data for comparison. Flow diagrams should be made mandatory for publication by journals, and the flow diagram should match the CONSORT Flow Diagram for RCTs.

Guideline implementation and recommendation adherence

This guideline, the AAPD's first evidence-based guideline on non-vital pulp therapy, is published in both the journal *Pediatric Dentistry* and *The Reference Manual of Pediatric Dentistry*. Additionally, AAPD members will be notified of the new guidelines via social media, newsletters, and presentations. The guidelines are available as an open-access publication on the AAPD's website.

Guidelines are used by insurers, patients, and health care practitioners to determine the quality of care. Adherence to guideline recommendations is measured because it is believed following best practices reduces inappropriate care and improves outcomes.

Cost-effectiveness of recommendations. The cost-effectiveness of treatment is based on initial and possible retreatment costs of an intervention.³² A cost-analysis for therapies with proven health benefits and minimal adverse effects is an important consideration for clinicians, patients, and third-party payors.³² This is especially important when different procedures with similar outcomes are available to treat a specific condition, as with non-vital pulp therapies. A research brief covering claims data for all children with private dental insurance does not list non-vital pulp therapies in primary teeth as one of top 25 most common procedures performed in children with private dental benefits, but it lists extractions.³³ The few non-vital pulp therapies performed on a population level compared to extraction is a cost-effective treatment health issue since extraction may require a space maintainer to prevent space loss and malocclusion. However, very limited data exist on the cost-effectiveness of non-vital pulp therapies in the primary dentition versus tooth extraction. An extraction alternative may be determined based on both cost-effectiveness and quality of life, as maintaining the integrity of the arches has many implications on function and the development of the occlusion. Pulpectomy is a procedure reimbursed by both private and federally funded insurance companies; however, LSTR is not listed as a specifically coded procedure. Reimbursement of more conservative approaches of pulp therapy aimed at preserving a tooth, such as a pulpctomy and LSTR, will allow clinicians to make conservative choices based exclusively on efficacy and effectiveness of the specific procedures.³⁴ Clinicians should also make their decision taking into consideration the age of the child at the time of treatment, as the longest follow-up times of the studies used as a basis for these recommendations are 18 months.

In light of the high but relative short-term success of non-vital tooth therapies, further studies are needed to investigate the cost-effectiveness of preserving primary molars with non-vital tooth procedures versus the alternative of extraction and need for space maintainers before and after the eruption of the permanent first molar.

The cost of pulp treatment may be contained by using effective medicaments, as determined by evidence-based research and detailed in this guideline; however, the only way to

reduce costs overall is to establish dental homes for every child and implement primary prevention by the child's parents or caregiver. Primary prevention must start early if treatment costs are to be reduced and oral health maintained.

Workgroup and stakeholders. In December 2018, the AAPD Board of Trustees approved a WG nominated by the Evidence-Based Dentistry Committee to develop a new evidence-based clinical practice guideline on non-vital pulp therapies in primary teeth with deep caries lesions. The WG consisted of pediatric dentists in public and private practice involved in research and education; the stakeholders consisted of representatives from general dentistry, governmental and nongovernmental agencies, and international and specialty dental organizations.

External stakeholders. External and internal stakeholders reviewed the document during the process of development of the guideline. Internal stakeholders also participated in anonymous surveys to determine the scope and outcomes of the guideline. All stakeholder comments were considered and addressed in the WG meetings. It is expected that the publication and dissemination of the guideline will generate additional dialogue, comments, and feedback from professional, academic, and community stakeholders.

Intended users. The target audiences for this guideline are dental team members in private, dental school, or public health care settings such as pediatric dentists, dental educators, general dentists, public health practitioners, policymakers, program managers, third-party insurers, dental students/residents, and parents/guardians. The target populations include children needing non-vital pulp therapy in primary teeth.

Guideline updating process. The AAPD's Evidence-Based Dentistry Committee will monitor the biomedical literature to identify new evidence that may impact the current recommendations. These recommendations will be updated five years from the time of the last systematic search unless the Evidence-Based Dentistry Committee determines that an earlier revision or update is warranted.

References

1. Coll JA, Vargas K, Marghalani AA, et al. A systematic review and meta-analysis of nonvital pulp therapy for primary teeth. *Pediatr Dent* 2020;42(4):256-72.E11-E199.
2. American Academy of Pediatric Dentistry. Pulp therapy for primary and immature permanent teeth. *The Reference Manual of Pediatric Dentistry*. Chicago, Ill., USA: American Academy of Pediatric Dentistry; 2019:353-61. Available at: "<https://www.aapd.org/research/oral-health-policies--recommendations/pulp-therapy-for-primary-and-immature-permanent-teeth/>". Accessed September 4, 2020.
3. Guyatt G, Oxman AD, Akl EA, et al. GRADE guidelines: 1. Introduction—GRADE evidence profiles and summary of findings tables. *J Clin Epidemiol* 2011;64(4):383-94.
4. Schünemann H, Brożek J, Guyatt G, Oxman A. Recommendations and their strength. Going from evidence to recommendations. *GRADE Handbook*. Available at: "<http://gdt.guidelinedevelopment.org/app/handbook/handbook.html>". Accessed September 4, 2020.
5. Schünemann H, Brożek J, Guyatt G, Oxman A. Quality of evidence. *GRADE Handbook*. Available at: "<http://gdt.guidelinedevelopment.org/app/handbook/handbook.html>". Accessed September 4, 2020.

6. American Academy of Pediatric Dentistry. Introduction: Overview. *The Reference Manual of Pediatric Dentistry*. Chicago, Ill., USA: American Academy of Pediatric Dentistry; 2019:7-9. Available at: "<https://www.aapd.org/research/oral-health-policies--recommendations/overview/>". Accessed September 4, 2020.
7. Mutluay M, Arikan V, Sari S, Kisa Ü. Does achievement of hemostasis after pulp exposure provide an accurate assessment of pulp inflammation? *Pediatr Dent* 2018;40(1):37-42.
8. Trairatvorakul C, Detsomboonrat P. Success rates of a mixture of ciprofloxacin, metronidazole, and minocycline antibiotics used in the non-instrumentation endodontic treatment of mandibular primary molars with carious pulpal involvement. *Int J Paediatr Dent* 2012;22(3):217-27.
9. Jaya AR, Praveen, Anantharaj A, et al. In vivo evaluation of lesion sterilization and tissue repair in primary teeth pulp therapy using two antibiotic drug combinations. *J Clin Pediatr Dent* 2012;37(2):189-91.
10. Grewal N, Sharma N, Chawla S. Comparison of resorption rate of primary teeth treated with alternative lesion sterilization and tissue repair and conventional endodontic treatment: An in vivo randomized clinical trial. *J Indian Soc Pedod Prev Dent* 2018;36(3):262-7.
11. Wankhade AD, Kumar R, Singh RK, Chandra A. Root length determination by different methods in primary teeth: An in vivo study. *Pediatr Dent* 2013;35(2):e38-e42.
12. Coll JA, Josell S, Casper JS. Evaluation of a one-appointment formocresol pulpectomy technique for primary molars. *Pediatr Dent* 1985;7(2):123-9.
13. Rawson TH, Rayes S, Strizich G, Salazar CH. Longitudinal study comparing pulpectomy and pulpotomy treatments for primary molars of Alaska Native children. *Pediatr Dent* 2019;41(3):214-20.
14. Moranker R, Goya A, Gauba K, et al. Manual versus rotary instrumentation for primary molar pulpectomies: A 24-months randomized clinical trial. *Pediatr Dent J* 2018;28(2):96-102. Available at: "<https://www.semanticscholar.org/paper/Manual-versus-rotary-instrumentation-for-primary-A-Moranker-Goyal/fc808b558de6aff5892fd2bdd84eb934230cd991>". Accessed September 18, 2020.
15. Subramaniam P, Tabrez TA, Girish Babu KL. Microbiological assessment of root canals following use of rotary and manual instruments in primary molars. *J Clin Pediatr Dent* 2013;38(2):123-7.
16. Kummer TR, Calvo MC, Cordeiro MMR, et al. Ex vivo study of manual and rotary instrumentation techniques in human primary teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;105(4):e84-e92.
17. George S, Anandaraj S, Issac JS, John SA, Harris A. Rotary endodontics in primary teeth – A review. *Saudi Dent J* 2016;28(1):12-7.
18. Coll JA, Josell S, Nassof S, et al. An evaluation of pulpal therapy in primary incisors. *Pediatr Dent* 1988;10(3):178-84.
19. Arikan V, Sonmez H, Sari S. Comparison of two base materials regarding their effect on root canal treatment success in primary molars with furcation lesions. *BioMed Res Int* 2016;2016:1429286.
20. Holan G, Fuks AB. A comparison of pulpectomies using ZOE and KRI paste in primary molars: A retrospective study. *Pediatr Dent* 1993;15(6):403-7.
21. Flaitz CM, Barr ES, Hicks MJ. Radiographic evaluation of pulpal therapy for primary anterior teeth. *ASDC J Dent Child* 1989;56(3):182-5.
22. Sari S, Okte Z. Success rate of Sealapex in root canal treatment for primary teeth: 3-year follow-up. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;105(4):e93-e96.
23. Memarpour M, Shahidi S, Meshki R. Comparison of different obturation techniques for primary molars by digital radiography. *Pediatr Dent* 2013;35(3):236-40.
24. Rocha MJ, Cardoso M. Survival analysis of endodontically treated traumatized primary teeth. *Dent Traumatol* 2007;23(6):340-7.
25. Rafatjou R, Yousefimashouf R, Farhadian M, Afzalsoltani S. Evaluation of the antimicrobial efficacy of two combinations of drugs on bacteria taken from infected primary teeth (in vitro). *Eur Arch Paediatr Dent* 2019;20(6):609-15.
26. Hobson P. Pulp treatment of deciduous teeth. 2. Clinical investigation. *Br Dent J* 1970;128(6):275-82.
27. Stallaert KM, Sigal MJ, Titley KV, Andrews PB. A retrospective study of root canal therapy in non-vital primary molars. *Eur J Paediatr Dent* 2016;17(4):295-300.
28. Coll JA, Sadrian R. Predicting pulpectomy success and its relationship to exfoliation and succedaneous dentition. *Pediatr Dent* 1996;18(1):57-63.
29. Panchal V, Jeevanandan G, Subramanian EMG. Comparison of post-operative pain after root canal instrumentation with hand K-files, H-files and rotary Kedo-S files in primary teeth: A randomised clinical trial. *Eur Arch Paediatr Dent* 2019;20(5):467-72.
30. Topcuoglu G, Topcuoglu HS, Delikan E, et al. Postoperative pain after root canal preparation with hand and rotary files in primary molar teeth. *Pediatr Dent* 2017;39(3):192-6.
31. Sevekar SA, Gowda SHN. Postoperative pain and flare-ups: Comparison of incidence between single and multiple visit pulpectomy in primary molars. *J Clin Diagn Res* 2017;11(3):ZC09-ZC12.
32. Schwendicke F, Brouwer F, Stolpe M. Calcium hydroxide versus mineral trioxide aggregate for direct pulp capping: A cost-effectiveness analysis. *J Endod* 2015;41(12):1969-74.
33. Yarbrough C, Vujcic M, Aravamudhan K, Schwartz S, Grau B. An analysis of dental spending among children with private dental benefits. Health Policy Institute Research Brief. American Dental Association. April 2016 (Revised). Available at: "http://www.ada.org/-/media/ADA/Science%20and%20Research/HPI/Files/HPIBrief_0316_3.pdf". Accessed September 4, 2020. (Archived in WebCite® at: "<http://www.webcitation.org/6tVCB0KEY>")
34. Caffey E, Tate AR, Cashion SW. Are your kids covered? Medicaid coverage for essential oral health benefits. Technical brief. September 2017. Pediatric Oral Health Research and Policy Center, American Academy of Pediatric Dentistry. Available at: "<https://www.aapd.org/assets/1/7/AreYourKidsCoveredfinal.pdf>". Accessed September 4, 2020.